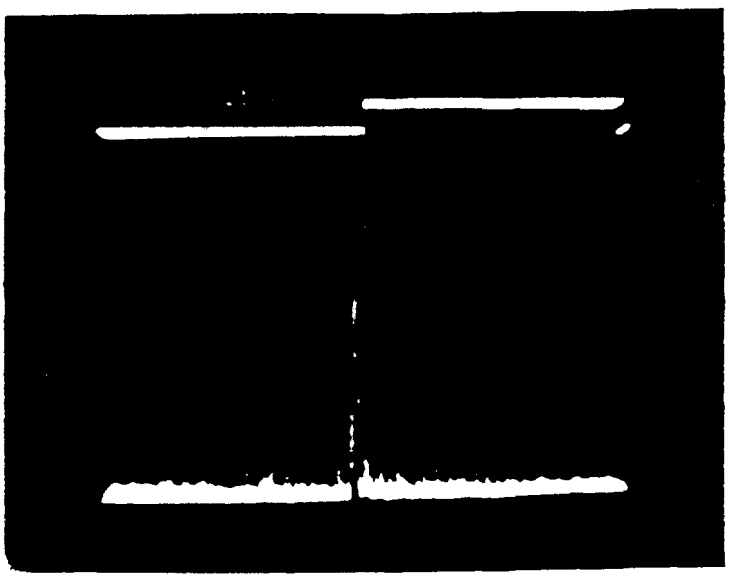
Transmitter And Receiver Are
Out-of-Sight Of One Another

500 ns Full Scale
20 ns Each Dwell

FIGURE 5.1

FIGURE 5.2

Transmitter And Receiver Are
Out-of-Sight Of One Another



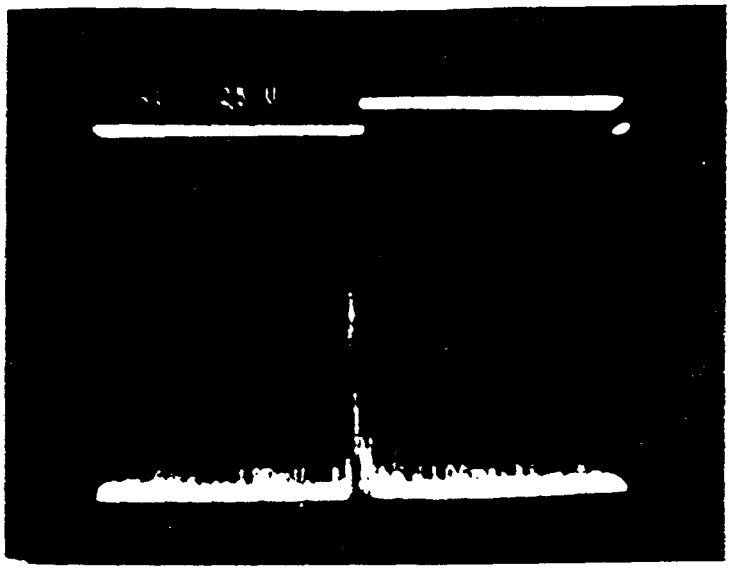
Scale: 5μs

FIGURE 5.3

Expanded
Scale: 500ns

FIGURE 5.4

Transmitter And Receiver Are
Out-of-Sight Of One Another



Scale: 5μs

FIGURE 5.5

Expanded
Scale: 500ns

FIGURE 5.6

6.0 CONCLUSIONS

This report considers the single, most important parameter in a Personal Communication System; *multipath,* and its effect on system performance.

It is shown that the received power lost due to fading (the fade margin) increases dramatically as the instantaneous bandwidth of a communication signal decreases below 11MHz. In particular, comparing the fade margins of a 1MHz and a 15MHz bandwidth signal shows a difference in fade margin of approximately 10dB.

In addition, using a modelling technique for out-of-sight communications, of the type typical for PCS, it was shown that multiple rays from a transmitter reach the receiver and only 1 to 3 of these rays have similar power levels. The remaining rays are attenuated by 3dB or more. It was also shown that the narrower the bandwidth of the spread spectrum signal the larger the number of rays which can occur within a chip duration and which are therefore correlated. Hence the greater the likelihood of a deep fade.

Further, it was shown that the multipath observed in practice had almost all of its power concentrated in a time interval of 100 to 500ns following the largest return. This result was also verified by photographs of out-of-sight multipath obtained using a RAKE receiver. If, however, a distant multipath signal return is seen, due to the reflection from a mountain or some distant building (a

situation far more likely in a rural setting rather than an urban setting), then, if this reflection was more than 1000 feet greater than the main signal ray returns, a 1MHz narrowband spread spectrum system could use a RAKE to collect this added reflected power.

While a wideband spread spectrum system could also use the RAKE to collect some additional energy, such collection is required by the narrowband system since its primary signal rays suffer the extra 10dB attenuation due to fading. Hence, it is not unlikely that in a narrowband CDMA system, the reflected power be of greater value than the in-close power, since both the in-close and far-out signals fade independently.

Based on the above theory and experiments, it is our conclusion that a wideband spread spectrum system, such as B-CDMA, be employed, which spreads the spectrum of the entire spectrum provided by the Commission. Such a system also provides, ISDN data rates, high quality voice, and can work indoor, where multipath signals are delayed by small time intervals, as well as outdoor, all without suffering dropped calls; the parameters required for a Personal Communications Service.

During the next quarterly report, SCS will obtain additional data to further demonstrate the advantages of a wide spectral allocation and the benefits of B-CDMA.

APPENDIX B

Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
Redevelopment of Spectrum to	)	ET Docket No. 92-9
Encourage Innovation in the	)	
Use of New Telecommunications	)	
Technologies	)	

To: The Commission

COMMENTS ON THE NOTICE OF PROPOSED RULEMAKING IN THE MATTER OF REDEVELOPMENT OF SPECTRUM TO ENCOURAGE INNOVATION IN THE USE OF NEW TELECOMMUNICATIONS TECHNOLOGIES

Prepared by:

SCS MOBILECOM, INC.

Submitted:
June 8, 1992

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Executive Summary

SCS Mobilecom, Inc. strongly supports the FCC's reallocation proposal as set forth in ET Docket 92-9. SCS has designed a novel technology Broad Band Code Division Multiple Access technology for emerging technology services, such as personal communications services, that will permit new and existing users to share spectrum if existing users choose not to migrate out of the band through market based negotiations. Sharing technologies, such as B-CDMA, are critical to the Commission's proposal. B-CDMA is the only system that can insure coexistence between new emerging technologies and fixed microwave users. Use of SCS' B-CDMA system can eliminate the need for the transition of fixed microwave users by replacing existing microwave systems with SCS' B-CDMA microwave system. Using this approach the density of fixed microwave users can even be increased, without significantly impacting the PCS system capacity. Further, using SCS' Dynamic Capacity Allocation (DCA) monitoring system, the status of the fixed microwave receiver can be continually monitored and the PCS system capacity continually adjusted to insure no excessive interference.

The Commission's allocation decision in this proceeding will be critical to the successful introduction of emerging technologies in the United States. There is currently a worldwide demand for new radio-based communications services, which by their very nature require the use of new, innovative technologies. Those services which are consumer oriented, such as the personal communications service, are price-sensitive and depend on their

ability to provide low cost services to the consumer. In addition to satisfying customer demand for reliable, continuous services, mobile services must also have a long battery life. These requirements can be achieved only in lower frequency bands such as those proposed by the Commission for reallocation to an emerging technologies band.

The Commission's spectrum allocation proceeding in ET Docket 92-9 is a crucial first step in permitting the rapid introduction of new technologies including PCS in the United States. Immediate and efficient introduction of PCS as the first beneficiary of the emerging technologies band will bring significant benefits to the U.S. economy and the American public. Clearly, PCS is critical for the United States to maintain the high quality and competitiveness of the U.S. telecommunications infrastructure as well as the U.S. telecommunications service and equipment manufacturing industry. Accordingly, the Commission should proceed expeditiously to create an emerging technologies band in this docket and initiate the necessary subsequent rulemaking proceeding to implement PCS at the reallocated frequencies. In that regard, SCS requests that at least 140 MHz of the targeted 220 MHz be subsequently allocated for PCS operations.

Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
Redevelopment of Spectrum to Encourage Innovation in the Use of New Telecommunications Technologies	)	**ET Docket No. 92-9**

To: The Commission

COMMENTS OF SCS MOBILECOM, INC.

SCS Mobilecom, Inc. ("SCS") hereby submits its comments to the Notice of Proposed Rulemaking in the above-captioned proceeding released on February 7, 1992.

SCS strongly believes the public interest requires the Commission to proceed with its spectrum allocation rulemaking in ET Docket 92-9 as expeditiously as possible in order to bring personal communications services ("PCS") and other new technologies to the American public as soon as possible. As discussed below, services such as SCS' broadband code division multiple access system ("B-CDMA") proposed for the 2 GHz band provide an alternative to the Commission's transition plan. SCS' B-CDMA system facilitates sharing of the 2 GHz band, between existing users and the new emerging technology licensees.

INTRODUCTION AND BACKGROUND

SCS is a leader in digital wireless telecommunications technology development. The Company has developed a unique broadband spread spectrum code division multiple access (B-CDMA) modem which allows extremely efficient use of the spectrum. SCS is currently licensing and negotiating licenses to use this technology in wireless PBXs, cordless phones, as well as other telecommunications products operating on an unlicensed basis pursuant to the Part 18 Industrial, Scientific and Medical ("ISM") rules and the Part 15 low power radio frequency rules.

SCS wholeheartedly supports the Commission's decision to allocate spectrum to an emerging technologies band that will foster the introduction of emerging technologies. The rapid and efficient introduction of these technologies -- which include personal communications services ("PCS"), mobile satellite services, digital audio broadcasting and low earth orbit satellite services -- will significantly benefit the American public and the U.S. economy. They will also play a key role in the United States effort to maintain a superior telecommunications infrastructure and the competitiveness of the United States equipment manufacturing industry.

SCS agrees with the Commission that creating a spectrum reserve band will significantly promote the introduction of emerging technologies thus bringing these important benefits to the American public.[1] Designating appropriate spectrum for emerging technologies is

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[1] See Notice at ¶ ¶ 7 and 8.

the most critical step in the implementation of emerging technologies in the United States. Once spectrum is identified for these new technologies, manufacturers and prospective service providers will be in a position to complete the equipment and service offerings that will make specific emerging technologies a reality in the United States. In particular, SCS, along with many other companies and users in the United States, believes that spectrum reallocation is crucial specifically for the rapid introduction of PCS.

SCS also shares, however, the Commission's view that, under the current spectrum shortage in this country, the Commission must develop a plan that "includes specific provisions for minimizing the impact on existing users."[2] In that regard, SCS recognizes the legitimate concerns of existing fixed microwave users, as does the Commission, that the creation of an emerging technologies band may adversely affect their microwave operations if they are forced to migrate to other frequencies without adequate assurance that their new spectrum "home" will be suitable for private microwave operations. Based on that concern, the Commission has asked that a suitable transition plan be proposed.

SCS' service proposal eliminates the need for a transition plan. As discussed herein, SCS's B-CDMA technology will allow microwave users to remain in their existing band and coexist with emerging technology services such as PCS and other B-CDMA technology users. Under SCS' proposal, fixed users could remain in their existing band and coexist with the B-CDMA technology users without interference. SCS' PCS system also

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[2] Notice at ¶ 6.

incorporates a Dynamic Capacity Allocation ("DCA") monitoring system that provides added assurance that microwave users will not experience even minimal disruption from PCS services sharing the band.

Accordingly, PCS and other emerging technologies can be implemented using technologies, such as SCS' B-CDMA system, that do not require the immediate or wholesale migration of existing microwave users to other spectrum bands and that can protect microwave users from interference. The full spectrum sharing features of such services thus eliminates the need for any transition plan.

1.0 THERE IS A COMPELLING NEED TO IDENTIFY SPECTRUM FOR PERSONAL COMMUNICATION SERVICES

1.1 The Commission Should Expeditiously Allocate Suitable Spectrum for Emerging Technologies

There is a strong worldwide demand for advanced new wireless communications services. These services by their very nature require the use of new, innovative technologies. SCS' B-CDMA PCS System, whose unique features are described in Appendices A - F, provides the spectrum efficiency and superior quality that can meet this demand.

The purpose of these Comments is to encourage the Commission to move forward as quickly as possible in allocating the proposed spectrum to these new technologies. Further, since PCS is a newly emerging technology, as defined by ET Docket No. 92-9, which requires a wide bandwidth to maximize quality and capacity and as low a frequency band as possible to minimize cost and maximize battery life, SCS recommends that the Commission allocate 140 MHz to the 1850-2200 MHz band from the proposed emerging technologies band.

1.2 1.85 GHz to 2.2 GHz is an Ideal Band for PCS

The Commission correctly selected the frequency bands of 1850-1990 MHz, 2110-2150 MHz and 2160-2200 MHz for emerging technologies.

SCS recognizes that this spectrum selection represents the Commission's initial identification of spectrum that will be reserved for emerging technologies and that further proceedings will be required before the selection of frequencies are allocated to any particular service. In particular, further proceedings will be required to consider the particular services to be accorded spectrum, how much spectrum is to be accorded each service and whether solid blocks of frequency or scattered "chips" of frequency should be allocated. Nonetheless, the Commission should consider generally the likely intended uses of the spectrum in rendering its spectrum allocation decision in this proceeding.

SCS believes that large blocks of frequency should be allocated to emerging technologies in order to ensure that services such as PCS operate with maximum capacity and provide high quality voice and ISDN rate data. As recognized by the Commission, the emerging technologies identified in the Commission's Notice of Proposed Rule Making will require a wide bandwidth for efficient communications.[3] This is particularly true for PCS since fading can be minimized efficiently only if the bandwidth employed is wider than the coherence bandwidth of the expected fade. SCS has performed numerous experiments to determine the coherence bandwidth of the fade [1, 2, 3, 4, 5] and has demonstrated conclusively that the coherence bandwidth of an indoor fade is typically 4 MHz wide and almost never exceeds 10 MHz. Similarly the coherence bandwidth of an outdoor fade is typically 3 MHz and, again, almost never exceeds 10 MHz. Thus, a communication signal having a bandwidth of 40 MHz or more is relatively unaffected by the fade while a signal

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[3] Notice at ¶ 9 (discussing need for wide band of frequencies).

having a bandwidth of 2 MHz or less is continually affected by fading, as are the current cellular and cordless telephones. This comparison reflects the significant difference between narrowband technologies, and broadband technologies, such as SCS' B-CDMA, and the relative vulnerability of narrowband systems to fading. See also Appendix B.

The bandwidth of 35 MHz for example, will permit a duopoly, i.e., two, full-duplex systems to operate independently in a total bandwidth of 35 x 4 = 140 MHz. SCS therefore requests that four blocks of spectrum, each having a bandwidth of at least 35 MHz, be set-aside for PCS. Such a spectrum allocation will serve a maximum number of users and will permit the efficient sharing of the band with the existing fixed microwave users.

There are additional parameters that must be considered in the choice of a suitable spectrum some of which the Commission considered in identifying the spectrum for reallocation. In particular, the Commission must consider the cost of the equipment and the need for long battery life.[4]

- **Higher frequencies require more expensive equipment.** At frequencies exceeding 2 GHz, Gallium-Arsenide (GaAs) rather than silicon is used for the RF transmitter and receiver operations. The use of GaAs increases cost as well as power consumption, thereby decreasing battery life.

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[4] See Notice at ¶ 10.

- **Lower frequencies produce less attenuation/unit distance.** For example, to transmit a signal over a given distance so that it can be received at a given power level, requires that the transmitted power be increased 100 times, for every 10-time increase in frequency. Thus, PCS handsets, which are battery powered and for which users demand a long life, require operation at the lowest possible frequency spectrum.[5]

For PCS, the Commission identified the frequencies particularly well suited for this service. The lowest frequency band currently targeted for this application is the 1850-2200 MHz band proposed by the Commission. A PCS system designed to operate with high quality voice and with wideband data should operate at as low a frequency band as possible to decrease the cost of the handset and maximize battery "charge" times.

1.3 The American Public Demands Wire Line Quality Voice, Wideband Data Rates and Wireless Convenience

The spectrum decision made in this proceeding, based on the factors discussed above, will be critical in determining the success of emerging technologies, such as PCS, in the United States. Society today is more mobile than ever before. As a result, whether at home, in the office, or on vacation, Americans require access to mobile telephone systems that offer high quality voice and wideband data capability. When cellular communications

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[5] On the other hand, a communication system which is not battery operated, or which operates for only short time intervals, or which operates over relatively short distances could readily operate at higher frequency bands.

systems first became popular, people bought the systems because the need to communicate was deemed to be so high, it overrode the poor quality and intermittent reception obtained. The arrival of the cordless telephone could have been used for business as well as at home, except that the intermittent reception made business usage unacceptable. As people continued to use these systems their expectations increased: the total lack of privacy became an issue as people realized that their telephone conversations on their cellular or cordless telephone could become public knowledge; and people started to demand data transmission using their cellular and cordless phones to transmit computer modem and facsimile information.

PCS will provide the user with a single service that can be used in and around the home, in lieu of the cordless phone; in the car, in lieu of the cellular phone; and in the office as part of a wireless PBX, in lieu of a PBX. The wireless PCS phone will have a capability of 10,000 codes (so that call interference in a cordless phone due to blocked channels does not occur); it will have wire-line voice quality; and will be able to transmit data at rates up to 144kb/s (ISDN rates). The transmission will be immune to fading so that calls will not be disconnected or have large bursts of errors.

This service, which will compete with the cellular service currently available, will produce a competitive atmosphere, improving performance of all wireless services and significantly reducing the cost of a call.

The technology needed to achieve this high level of performance in the PCS frequency band is Broadband-Code Division Multiple Access, B-CDMA.

Today, the public is not content with the wireless service afforded it. Consequently, there is a substantial consumer population waiting for a wireless telephone product with the capabilities of a wired telephone. This market need can be met by the PCS system proposed by SCS Mobilecom, but only if the Commission takes the first step of identifying suitable spectrum for PCS and allocating that spectrum for PCS use. SCS submits that the Commission can reallocate spectrum for PCS use on a shared basis with existing users using sharing approaches such as SCS' B-CDMA system.

2.0 BROADBAND-CDMA CAN EASE THE PAIN OF TRANSITION

The Commission, in Paragraphs 22-26 of the Notice discusses a possible Transition Plan. The stated intent of the proposed Transition Plan is to "reaccommodate the 2 GHz licensees in a manner that is most advantageous for these existing uses, least disruptive to the public and the most conducive to the introduction of new services." Notice at ¶ 22. SCS is acutely aware of the difficulties raised by the Commission's proposal to displace existing users to other bands, particularly under the current severe spectrum shortage in the United States. In this regard, SCS fully supports the Commission's public interest objectives and proposes a plan to allow a smooth introduction of new services, during the transitioning of existing users from the portion of the spectrum devoted to emerging technologies, with an option which will allow existing users to coexist indefinitely on the band if they desire to remain. Thus, SCS' sharing system can substantially ease the pain of this transition.

2.1 B-CDMA Users Can Coexist With Microwave Users

Broadband-CDMA permits coexistence of emerging technologies, such as PCS, and the existing fixed service microwave users. However, such coexistence limits the number of new licensed users in a PCS cell. Thus, as the number of PCS users/cell increases, a point will be reached where additional user density will require a reduction in the fixed microwave user density. Thus, SCS' B-CDMA service plan permits the fixed microwave user exodus to be gradual rather than abrupt. Further, we describe below a spread

spectrum microwave system that, if employed by the fixed microwave user community, will allow all microwave users to remain on the band indefinitely.

2.1.1 Coexistence: Limitations on User Density

Coexistence means that the new users and existing point-to-point fixed service microwave users can use the same frequency band without either system noticeably interfering with the other system. In the case of the PCS system, degradation of quality, such as "noisy" speech or increased "outage-time" (an extremely common occurrence in the current cellular systems) would represent a lack of coexistence. For the fixed service microwave users, EIA Document 10E defines interference for digital and analog microwave systems.

In order to obtain the limitation imposed by Document 10E, the microwave transmitter typically attenuates its output, by about 40 - 50 dB, until the measured bit error rate (BER) in the receiver is 10^{-6}. At that point, the transmitted PCS signal power (which is the interference seen by the microwave) is increased until the BER increases to 10^{-6}. This is the maximum allowable interference under 10E and, under these conditions, the maximum transmitted power of all the PCS users in the universe is required to be 6 dB below the thermal noise level of the fixed microwave receiver. Clearly, such a restrictive requirement limits the capacity of the B-CDMA system.

It is most interesting to note, however, that a fade of 40-50dB may occur for perhaps 20 seconds a year. (There are 37 million seconds a year). In New York the electric power generated by Con Edison or LILCO is cut-off for far more than 20 seconds a year without disastrous consequences.

If, during the 20 second period, a PCS user is in the boresight of the microwave antenna, and this PCS user does not suffer the same fade, then during 20s a year, coexistence will not be possible.

Experimental results were performed by SCS for Millicom in Houston and Orlando which verified that coexistence is achievable. These test results are summarized in Appendix D.

2.2 Dynamic Capacity Allocation

Even though the evidence is clear that there is a low probability of excessive interference to the fixed microwave user by a new PCS user in a shared spectrum environment, the fixed microwave user is rightfully justified in arguing that from "Murphy's Law" excessive interference will occur during a catastrophe. This concern was stated most forcefully by the UTC's petition to defer action on this NPRM.

As noted by SCS, in response to the UTC petition[6], SCS has developed a Dynamic Capacity Allocation (DCA) monitoring system[7] which monitors each fixed microwave receiver, and with a dedicated line communicates the pertinent measured information to the PCS base stations. The base stations can then regulate traffic in each cell to insure that there is not any excessive interference.

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[6] SCS Mobilecom, Inc. Comments on the UTC Petition for Rulemaking, FCC RM-7931, May 28, 1992.

[7] Patent Pending

2.3 B-CDMA Microwave Systems Can be Used by Fixed Microwave Users to Allow Coexistence Without Noticeably Limiting PCS Capacity And to Allow an Increase in the Fixed Microwave User Density

The analog and digital microwave systems used today are sensitive to external interference. However, if these systems were replaced by Broadband-CDMA microwave systems[8] such sensitivity would be significantly reduced and the number of fixed microwave users per square mile could be substantially increased.

It is shown in Appendix E that each fixed microwave user operating at 43 Mb/s transmits at the same data rate as 672 PCS users, who are transmitting digitized voice at the rate of 32 kb/s. It is further shown that the PCS user density is 67,200 users/square mile. Hence, if the density of fixed microwave users is as high as 1 per square mile, the fixed microwave user would constitute only 1% of the available PCS capacity. Further, if the number of fixed microwave users were increased substantially to 10 fixed microwave users/square mile that still would constitute only 10% of the entire PCS capacity.

Therefore SCS strongly recommends that the fixed microwave users be encouraged to use B-CDMA microwave systems so that they could remain on the band indefinitely and coexist with the PCS users with only a negligible impact on the capacity of the PCS system.[9]

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[8] Patent Pending

[9] Since the use of SCS' proprietary technology is required for a system solution, SCS is prepared to license the technology to multiple (continued...)